A LEGISLATOR'S GUIDE TO LANDSAT

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Prepared by
The National Conference of State Legislatures
Remote Sensing Project

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The National Conference of State Legislatures wishes to express its appreciation to the National Aeronautics and Space Administration for its support and cooperation in producing this booklet.

Cover Photo: The picture on the front cover represents an unsupervised land cover classification of the Island of Hawaii produced by computer analysis of Landsat data acquired on February 11, 1973.

Original photography may be purchased
from EROS Data Center
Sioux Falls, SD 57198

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I. THE IMPORTANCE OF LANDSAT TO STATE GOVERNMENT

Landsat, formerly known as ERTS (Earth Resources Technology Satellite) is an earth orbiting satellite which transmits a steady flow of information about the earth's surface to ground-based receiving stations. It is an effective tool for inventorying and analyzing natural resources and is being used for this purpose by many federal, state, regional and local agencies as well as private entities. The new satellite technology requires relatively little investment but yields important benefits to state decision-makers. Its principal advantage is that, for many applications, it can provide more useful information on a more timely basis and at lower costs than other available data sources. The intent of this guidebook is to show some of the ways state governments can best use this new technology for helping to solve policy and resource management problems.

Landsat is an effective means of helping to meet the natural resource data requirements of recent state and federal legislation. Examples of this environmental legislation include California's Coastal Zone Conservation Act, the Maryland Wetlands Act, the Mississippi Forest Practices Act and New York State's Mined-Land Reclamation Act. At the federal level, requirements such as those under the Water Pollution Control Act Section 208 and the Surface Mining Control and Reclamation Act of 1977 impose additional natural resource data needs on the states. Implementation of these state and federal programs calls for more comprehensive, timely and cost-effective data gathering and analysis than before. In many instances, Landsat can help to provide this data more efficiently.

The availability of Landsat data is beginning to have an impact on state legislative activities. Several state legislatures (e.g. the Virginia and Iowa General Assemblies) are conducting interim studies on Landsat and natural resource information systems technology. The Vermont General Assembly enacted a Forest Development Act during its 1978 session. Some of the statewide assessments called for in this act can only be completed in a cost-effective and comprehensive manner utilizing Landsat data. There are many other potential legislative impacts of Landsat technology. The availability of this new tool creates many possibilities for state initiatives in areas such as water resource policy, resource development policy, natural resource management, water quality planning, environmental monitoring, coastal zone management and many other policy areas of direct concern to the state legislative community.

Landsat is highly applicable for many of the data requirements of natural resources programs. Information on current land cover, surface water location and wildlife habitat, for example, is needed for virtually all natural resource studies, and Landsat has been found especially effective in providing this information. Landsat is not the solution for all natural resource problems. It is, however, an important tool which, when used appropriately with other information sources, can help solve many crucial environmental problems. It is important, therefore, to understand Landsat's potential benefits and limitations in order to use it to greatest advantage.

The appropriate use of Landsat derived information with other data sources can best be achieved within the framework of a comprehensive natural resource information system. Such a system provides the framework for spatial data entry, manipulation, analysis, comparison and output required to effectively integrate data from many sources. By providing staff, hardware and software for a comprehensive natural resource information system as a centralized service, economies of scale can be realized and duplication of effort reduced.

II. LANDSAT OVERVIEW

Chronology

The first Landsat (then called ERTS-1) was launched by the National Aeronautics and Space Administration (NASA) in July, 1972. Its purpose was to demonstrate the value of continuous, worldwide data gathering from an orbital platform. Landsat-2 was launched in January, 1975, and its orbit was synchronized with that of Landsat-1 so that together, cloud cover permitting, they could provide almost complete global coverage every nine days. Landsat-1, with an expected "life-span" of one year, functioned until January, 1978. A third satellite, Landsat-3, was put into orbit March 5, 1978, so that once again nine-day interval coverage was achieved. To maintain continuity of data, all three of these satellites have carried essentially the same instrumentation and have circled the earth at the same altitude.

How It Works

Landsat orbits the earth 14 times each day at an altitude of about 560 miles. Each satellite returns to the same orbit every 18 days recording the same series of images. There are two sensor systems on board, a Return-Beam Vidicon (RBV) system, which is basically a television sensor, and a multi-spectral scanner (MSS) which records differences in sun reflectance from earth-surface features. The RBV system has been used relatively little in the experimental mode of Landsat-1 and -2; however, it will be more thoroughly evaluated in Landsat-3.

The multi-spectral scanner records information in both the visible wave lengths and in parts of the electromagnetic spectrum which are invisible to the eye and to camera systems. The MSS takes four readings for each 1.1 acre area on the ground — one for the intensity of green light reflected, one for the intensity of red light reflected, and two for the intensity of infrared. These intensity levels are converted into digital form and are transmitted back to ground receiving stations on earth. Data for any part of the United States are transmitted to one of three U.S. receiving stations. There are seven others at present throughout the world, with several more being planned.

From the receiving stations the data is relayed to the Master Data Processing Facility at Goddard Space Flight Center in Greenbelt, Maryland, where it is stored on computer-campatible tapes (CCTs). The data can be converted from the tape format into photograph-like images in black and white or color. Reproducible negatives and computer tapes are then sent to the Earth Resources Observation System (EROS) Data Center in Sioux Falls, South Dakota, for storage and distribution.

Satellite photographs and tapes can be ordered directly from EROS. The photographs are generally available as prints or transparencies, in sizes of 9" x 9", 20" x 20", or 40" x 40". The tapes are available in several formats to accommodate different types of computers.

How Landsat Data Is Analyzed

Landsat data can be used in either its photographic form or in its computer-tape (digital) form. If the photographic products are chosen for analysis the procedures are almost identical to those used for interpreting conventional aerial photographs. Landsat's much smaller scale, making objects appear smaller than on aerial photos, is the principal difference.

As with aerial photo interpretation, the materials needed can range from nothing more than a pencil and transparent paper to sophisticated optical instruments costing several thousand dollars. Very often, analysis of Landsat photos can be done with materials already on hand.

Computer processing of Landsat data is somewhat more complicated than photo interpretation but is faster and yields more detailed results. The computer can normally identify objects of as little as 1.1 acre while photo interpretation techniques are generally limited to objects of 10 acres or larger. While computer processing of Landsat obviously requires more expensive equipment than photo interpretation, it can generally be done using small computers ("mini computers") already available in many state agencies. The costs involved in using Landsat, even through computer processing, need not be a deterrent for any state government. Typical costs are discussed in the next section and are illustrated in Tables I and II.

Advantages of Landsat

Landsat has several unique advantages which make it attractive to state resource decision makers and planners. Cost and time comparisons invariably indicate the advantages of Landsat over aerial photography and other data sources. Table I shows a cost comparison prepared by the Texas Natural Resources Information System (TNRIS) between the use of Landsat and aerial photos for mapping a small pilot area of forest land in East Texas, and the projected costs of mapping the entire eleven million acre commercial timber zone.

TABLE I
Cost Comparisons for Mapping East Texas Forest Lands

	Total Cost	Time Required
Pilot Project — Landsat	$ 1,016	3-4 man weeks
Pilot Project — Aerial Photos	1,050	2 man weeks
*Entire Area — Landsat	10,289	4 man months
*Entire Area — Aerial Photos	294,000	10.7 man years

*Extrapolated

The above figures illustrate very well the cost effectiveness and timeliness of Landsat for large area projects. In fact, survey of the entire area by aerial photos can be ruled out by the 10 year delay in project completion without even considering the near 30:1 cost advantage of Landsat.

Typically, land use/land cover mapping can be accomplished with Landsat at one-half (1/2) to one-twentieth (1/20) the cost of conventional techniques. The Southwestern Illinois Metropolitan Regional Planning Commission (SIMPAC) reported a fourteen-fold cost reduction for land cover mapping by using Landsat instead of windshield surveys (surveys conducted from automobiles) for data collection (Table II). The extreme slowness of windshield surveys and the fact that only about 10% of the land area is actually viewed from the highways, are further reasons for preferring Landsat over ground-based data collection techniques.

Landsat's nine-day coverage cycle offers the capability for maintaining up-to-date natural resource information required in many environmental programs. Never before has it been economically feasible to collect aerial imagery over very large areas at such frequent intervals.

Landsat's computer compatibility is also an important advantage. Since the data is already in numerical form it can be used directly in geographic information systems to produce tabular summaries or in computerized plotting systems to produce maps and map overlays showing different aspects of the earth's surface such as land cover, vegetation and the location of water bodies. This information can be combined with soils, slope, rainfall and other data to produce natural resource atlas maps which, with the speed and efficiency of the computer, can be updated much more frequently than ever before.

The large area covered by a Landsat scene — about 115 miles on each side for a total of 13,000 square miles — offers the advantage of a broad perspective impossible with any other data source. It would take over 4,000 aerial photos at a scale of 1:20,000 to cover the same area, requiring a much larger investment in money, time and patience. Landsat eliminates data-handling problems associated with large numbers of aerial photos such as control of scale and sun angle, and other variables encountered in acquiring photography of large areas. Quite often, very wide-area features such as faults or other lineaments in the earth's surface are visible on Landsat but go undetected on aerial photographs because of the lack of a broad view of a single frame. Aerial photographs contain greater detail than Landsat but they provide it in a less comprehensive data format.

Another advantage is that Landsat can be used cost effectively to identify areas where more detailed information is needed. Individual diseased trees, for example, cannot be identified from Landsat data. Areas where the disease is prevalent, however, can be delineated and then these limited areas can be examined in more detail with aerial photography or ground observation. The investigator is spared the time and expense of analyzing detailed source material for the entire forest. In this manner, Landsat often serves to complement other data sources and increase their efficiency.

The complementarity of Landsat with other data sources is, in itself, an important advantage. Aerial photographs, topographic maps, soils data and socio-economic information frequently are collateral compo-

TABLE II
Cost Comparisons for Land Cover Inventories

	Ground Survey	Aerial Photo Interpretation	Landsat
	8 Years 40 Categories 3 Counties 1786 Sq. Miles	18 Months 5 Categories 3 Counties 1786 Sq. Miles	6 Months 16 Categories 7 Counties 3792 Sq. Miles
Maps, Photos or CCT	$ 130.90	$ 4,161.38	$ 400.00
Auto Travel Expense	570.90	Minimal	700.00
Inventory	55,000.00	17,056.00	3,792.00
Measure & Tabulate	30,000.00	8,528.00	3,700.00
Ground Checking			750.00
Map Preparation	20,000.00	5,969.00	5,615.00
Miscellaneous Supplies	500.00	135.00	1,000.00
TOTAL	$106,201.80	$36,049.38	$15,957.00
Per Square Mile	$ 59.46	$ 20.18	$ 4.20

nents of Ladsat-based studies. In most instances a combination of Landsat with other data types yields more complete and usable information than the Landsat data alone. The integration of Landsat with other data sources increases the value of the total information gathering system.

Limitations of Landsat

It should be kept in mind that, along with its advantages, Landsat has certain definite limitations. Chief among these are its relatively limited resolution or detail, the current two-month time lag between the date when the image is originally recorded and the time the data is made available to the user, and frequent cloud cover. The first two problems will be considerably alleviated with future improvements in the Landsat system (refer to section entitled "Future of the Landsat Program"). In the meantime, they will be significant barriers for many applications. Projects requiring fine detail, for identifying individual trees or urban features, for example, cannot rely entirely on Landsat but may require aircraft photography or other supplementary data sources. Many applications requiring very current coverage must also rely on other sources. Cloud cover will always be a problem particularly in some areas of the country. In actual fact, nine-day repetitive coverage is often impossible.

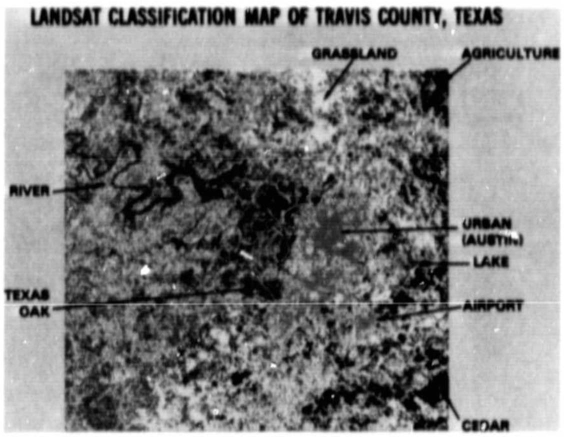
Despite its limitations, Landsat has unique qualities which make it useful to state government. It provides a "big picture" of conditions and interrelationships on the ground which might not otherwise be visible.

Single Landsat scenes sometimes cover entire ecosystems. These factors, combined with Landsat's potential nine-day repetitive coverage, low cost, computer compatibility and other advantages, point to satellite remote sensing as a useful tool to help meet state natural resources responsibilities.

III. LANDSAT APPLICATIONS

Landsat is used for a wide variety of purposes in the analysis and management of natural resources. Table III reflects some of the most frequent uses.

Land Resource Planning and Management



Landsat is particularly effective for providing land cover data, a prerequisite for many types of natural resource investigations. Many state agencies are using Landsat data to meet the requirements of the HUD 701 and EPA 208 legislation. South Dakota, Ohio, Texas and Illinois, and the North Carolina Triangle J and Ohio-Kentucky-Indiana Regional Councils of Government are among numerous state and local governments using Landsat data to help meet EPA 208 requirements. To be most useful, land cover data must be regularly updated. Landsat provides the best means available to provide these necessary updates.

The Landsat derived cover classification shown above, produced by a Texas state agency, depicts land cover patterns in the Austin, Texas vicinity, and is typical of the information which can be mapped by satellite.

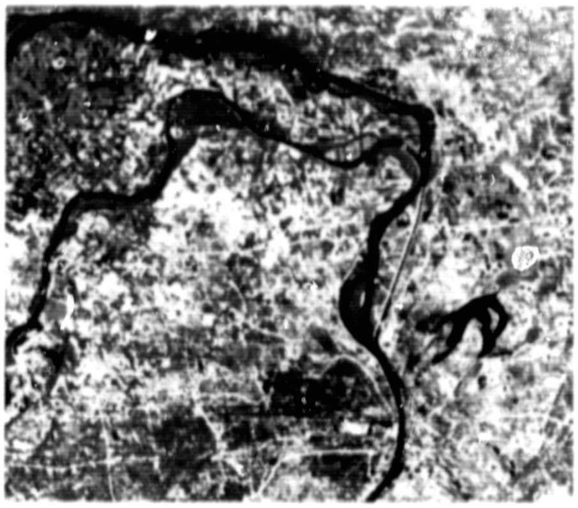
Landsat is useful for detecting changes in earth-surface features or activities. The repetitive coverage is ideal for monitoring urban expansion, deforestation, changes in water turbidity, the effects of rural development on wildlife habitat or a host of other items of interest in land resource planning and management. Changes can be detected either through manual interpretation or by means of special computer techniques.

TABLE III
Most Frequent State Applications of Landsat

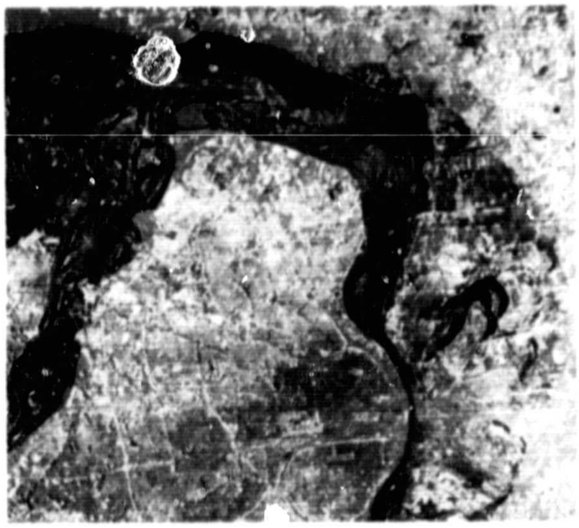
Land Resources Planning & Management	*Forest Management*
Land Use/Land Cover Mapping Change Detection Flood Plain Management	Timber Inventories Forest Harvest Monitoring Disease & Stress Detection
Water Resources	*Routing & Siting*
Mapping Lake Turbidity and Trophic Levels Detecting Water Pollution Sources Locating & Mapping Surface Water Bodies Mapping Snow Cover	Selecting Transportation Route Selecting Transmission Route Siting for Power Plants and Other Industries Siting for Solid Waste Disposal Siting for Water Impoundments
Coastal Zone Management	*Wildlife Habitat Analysis*
Detecting Coastal Land Use Change Monitoring Ocean Waste Disposal Measuring Shorelines Tracing Beach Erosion Tracing Oil Spills & Pollutants	Vegetation Mapping Determining Carrying Capacity Making Harvest Recommendations
Agricultural Applications	*Environmental Applications*
Crop Inventories Estimating Yields Monitoring Crop Disease Mapping Irrigated Fields Rangeland Management Assessing Drought Impact	Monitoring Strip Mining Monitoring Strip Mine Reclamation Studying Man's Impact on the Land
	Geologic Applications
	Mineral Exploration Detecting Hazard Zone Water Exploration Finding New Energy Sources

Planners find Landsat to be very useful in floodplain management. Regional drainage patterns and surface geologic features associated with floodplains are easily discernible, providing useful information to help plan for the development of floodplain areas.

Landsat, with a nine-day coverage cycle, is an excellent tool for recording fluctuations in water levels caused by drought or flood conditions. The availability of such current information allows states to more quickly and effectively deal with certain types of disasters. The photographs on the next page show the Mississippi River near St. Louis before and after its 1973 flooding.



Before flood -- October 2, 1972

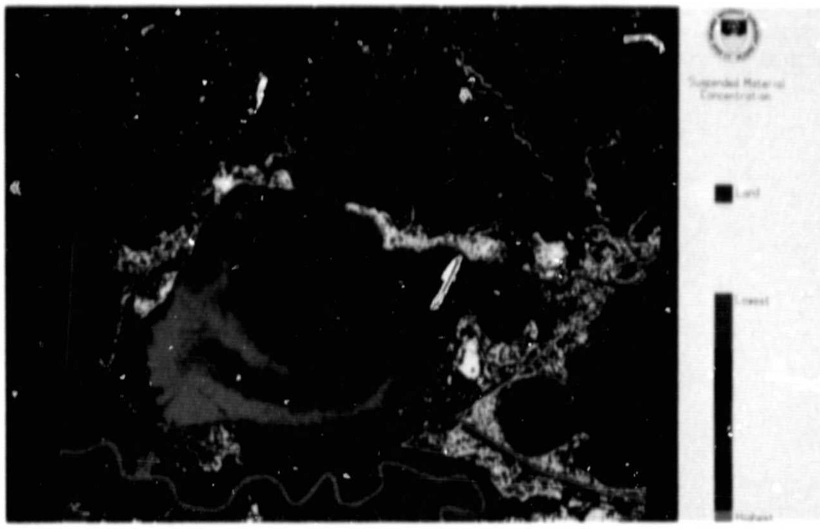


After flood – May 24, 1973

Water Resources Management

Landsat is useful for a number of applications in water resources management.

Biologists and other natural scientists are finding Landsat useful for monitoring lake turbidity (muddiness) and trophic levels (nutrient content). The Wisconsin Department of Natural Resources, for example, has used Landsat to classify about 3,000 of its inland lakes according to their trophic levels (nutrient levels). The Texas Department of Water Resources is conducting a lake water quality study with Landsat in an effort to establish a more accurate lake classification system than the one currently used by the national government for allocating Federal funds. Good success has been reported with Landsat in mapping lake water quality parameters in Saginaw Bay.

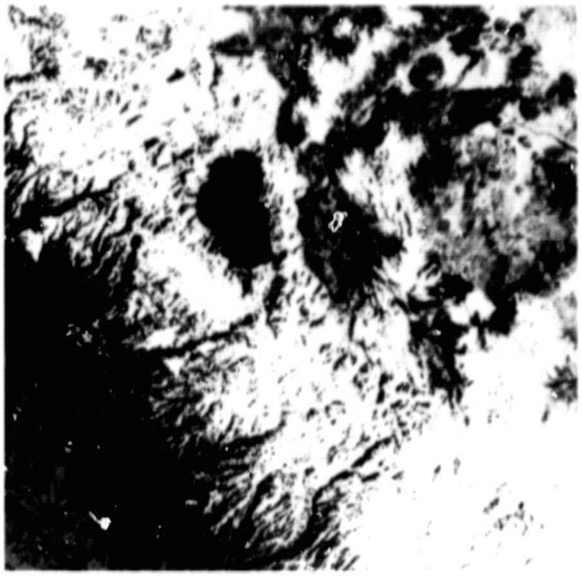


This Landsat image shows the amount and distribution of suspended sediment in Lake Ponchartrain, near New Orleans, Louisiana.

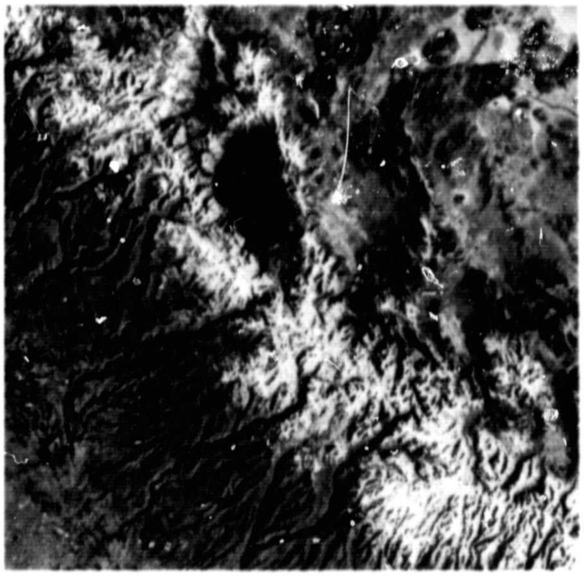
Non-point pollution sources (those generated over large areas such as feed lots, agricultural fields and harvested forests) can often be detected by Landsat. Landsat can also be used to detect and trace industrial effluents and to map turbidity patterns resulting from fresh water discharge into bays and estuaries. Botanists have used the satellite data for mapping the extent of aquatic plant infestations such as water hyacinth in Florida.

One of the most frequent uses of Landsat has been for locating and mapping surface water bodies. Lakes as small as five acres are visible on Landsat photo enlargements while computer processing reveals water bodies of as little as one acre in size. Some states are using Landsat photos for locating man-made reservoirs for permitting purposes. Computer-processed Landsat data will be the basis for locating reservoirs and dams throughout the Nation which will come under scrutiny of the National Dam Inspection Act of 1972 (PL92-367).

Snow-cover mapping by Landsat is of great importance for predicting the amount and rate of water runoff from the melting snow pack. In many parts of the United States this runoff provides a principal source of water for irrigation, industry, domestic use and recreation. In the past, forecasts have been made using time consuming and rapidly out-dated ground measurements and data from aerial photographs. Hydrologists using Landsat can now make more accurate forecasts in a fraction of the time and at much lower costs. Pictured on the next page are Landsat images of the Sierra Nevada Mountains of California and Nevada in which snowpack areas can be delineated easily. By integrating information on snow depth from ground stations with the snow-covered area estimates obtained from the satellite, accurate predictions can be made of future water runoff and anticipated water supplies within drainage basins. Landsat data has been used to map the extent of the snowpack in parts of the Central Rockies and, from that information, to predict the amount of water to be available for California farmers in the spring and summer. Similarly, Landsat data can be used to predict the extent of flooding from spring thaws.



February 25, 1975



February 14, 1977

ORIGINAL PAGE
COLOR PHOTOGRAPH

Coastal Zone Management

Landsat can provide a wide range of natural resource data required by Federal and state coastal zone legislation.

State planners are using Landsat for compiling current land cover maps which are necessary for evaluating the effects of man's activities on the ecologically fragile coastal zone. It has been found especially useful for detecting changes in coastal land cover. Botanists and others find Landsat appropriate for mapping coastal wetlands. The State of Georgia, for example, has used Landsat data to delineate coastal wetlands and to identify the area of fresh water/salt water interface.

Marine biologists use Landsat to monitor ocean waste disposal which often appears on the Landsat photographs as "ocean dump plumes", and to trace the movement of pollutants by ocean currents. Alabama planners have used satellite data to more accurately measure their State's shoreline. The New Jersey Department of Environmental Protection has found Landsat appropriate for a number of coastal applications including mapping land use change, monitoring ocean waste disposal and assessing shoreline erosion/accretion for the allocation of coastal zone funds. Other coastal zone applications include the detection and monitoring of oil spills and the charting of shallow coastal water. In short, Landsat offers a wide range of uses in the management of the coastal environment.

Agriculture

Landsat is useful for a variety of agricultural policy and program applications.

Crop inventories based on Landsat data have had good success since Landsat can identify most major crops, particularly through computer techniques. NASA's Large Area Crop Inventory Experiment (LACIE) shows good results and may be used in the future for estimating worldwide wheat yields. These timely estimates of wheat production could lead to better management of this important world food crop.

Agricultural experts have successfully used the satellite data to monitor crop disease, most notably during the midwest corn blight outbreak during the early 1970's. Hydrologists have used Landsat to map irrigated lands in order to estimate the volume of water being pumped from local aquifers. In Idaho, state officials used Landsat to update the inventory of four million acres of irrigated land along the Snake River.

Landsat is also a useful aid in rangeland management, particularly for classifying vegetation types and range conditions. Knowledge of range conditions provided by Landsat can be used to determine carrying capacity for a given season, plan for supplemental feed programs, predict fire hazards and for numerous other purposes of importance in the livestock industry.

Landsat is an effective tool for analyzing vegetation stress to assess drought conditions. It can also be used effectively to monitor the effect of drought on agricultural land cover, crop conditions, rangeland conditions and water supply/demand.

Pictured below is computer derived classification of irrigated lands produced by the Idaho Department of Water Resources.

BLUE - WATER
GREEN - IRRIGATED CROPS & PASTURE
MAGENTA - HARVESTED IRRIGATED CROPLAND
BROWN - FALLOW/BARE SOIL
TAN - DENSE HERBACEOUS RANGE
YELLOW - SPARSE HERBACEOUS RANGE

Forest Management

Federal and state-level agencies, as well as commercial timber companies, are finding Landsat to be an efficient data source in forest management.

To effectively manage commercial timber lands, detailed inventories are essential. Aerial photography, the conventional data source for such inventories, yields detailed information, but at a high cost in both money and time. Even then, the areas to be mapped are often so large that a sampling procedure, rather than total area mapping, is the only economically feasible approach. With Landsat, however, very large forest areas can be completely mapped, rather than sampled, at relatively low costs (refer to Table I, Page 6). Landsat can easily detect broad classes of timber resources such as deciduous, coniferous, mixed stands and several timber density levels. This level of detail is often sufficient for the forest manager's needs. If the Landsat analysis identifies areas of disease or other stress conditions, the forest manager can then acquire small amounts of lower altitude photography for closer inspection.

Pictured below is a Landsat-derived forest classification map of one county in Oregon.

Monitoring timber harvest and measuring the extent of clear cutting are also appropriate applications for Landsat. Landsat's repetitive coverage provides a means for monitoring the changes brought about by timber cutting, road building and fire. In Oregon, for example, Landsat revealed for the first time the extent of clear cutting in the remote timber areas.

Routing and Siting

State legislatures are showing increasing concern that new transportation and transmission routes, and facilities such as nuclear power plants, solid waste disposal sites, and certain industries, be located with a minimum impact on the environment. Landsat is a useful data source in this regard.

In Michigan, highway planners have merged Landsat data with information from aerial photographs and other sources to design prototype highway corridors based on environmental, social and economic considerations. The same approach can be used for locating power lines or other types of energy transmission corridors. Oil and natural gas companies make good use of Landsat for pipeline routing.

Georgia, as well as other states, has used Landsat for selecting locations for solid-waste disposal facilities. Others find the satellite data useful for selecting sites for water impoundments. No other data source provides the necessary broad-area coverage and perspective at equivalent costs.

Wildlife Habitat Analysis

The mapping and analysis of wildlife habitats by means of Landsat data is gaining wide acceptance. Urban sprawl, the conversion of forest to pasture and other encroachments of civilization on natural wildlife areas require current maps outlining the remaining natural habitats so that they may be better managed and protected for future generations.

Wildlife habitat mapping generally consists of defining specific vegetation zones which are identified with certain animal species. Wildlife biologists use this map information, along with other data, to determine population trends, carrying capacity and harvest recommendations. With Landsat, it is economically and technically feasible to conduct habitat mapping over large regions encompassing multiple ecosystems. Furthermore, Landsat's repetitive coverage allows these habitat maps to be maintained on a more current basis.

Geology

Geologists are finding Landsat to be of value for a variety of reasons. Potential mineral and ground water indicators such as faults, fractures and other linear features often are undetected on lower altitude photography or by field observation, but are evident on individual Landsat frames or mosaics. The Alabama Geological Survey, for example, has discovered high-yield ground water sources by mapping lineaments on Landsat photos. Similarly, scientists at the University of Nebraska's Remote Sensing Center have used Landsat to locate new ground water sources in that state's agricultural areas. These "linears" are also important as potential cave-in or landslide areas or possible earthquake zones.

Landsat also has important potential as a tool for discovering new sources of energy. Major petroleum companies are aware of this and have led the field in oil and gas exploration with Landsat. The thermal sensor on the recently-launched Landsat-3 is of special interest in regard to geothermal energy sources.

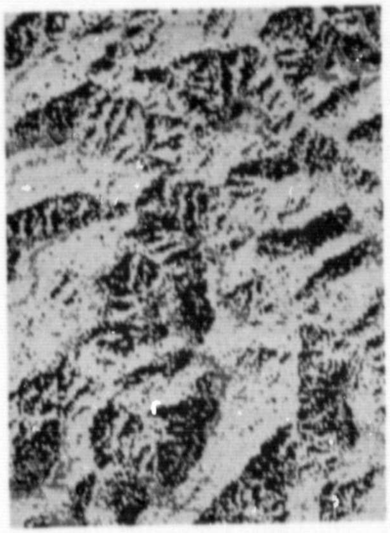
Surface Mine Monitoring and Reclamation

Landsat offers a useful means for analyzing and monitoring the impact of many of man's activities which are potentially harmful to the environment. The list could be long indeed and many of the applications have been listed under other headings. The applicability of Landsat to surface mining, however, deserves special attention.

Officials in the Appalachian, Midwest and High Plains states use satellite data to monitor surface mines and their conformance to reclamation standards. Landsat is also used to measure the extent of areas affected by surface mining in the past. The Maryland Geological Survey, for example, reported that Landsat has detected over 25% more affected land than had previously been estimated.

Many of man's broad-scale activities can be monitored and evaluated by satellite. Since Landsat has the capacity, with its wide-area coverage, to view these environmental elements in the context of a single system, it is an important tool for assessing these forces in an integrated way.

The growth of surface mining activity can be monitored using Landsat data. Pictured below are mined areas (in red) in the Appalachians on two different dates.



February 19, 1973

October 16, 1974

IV. INSTITUTIONAL APPROACHES TO LANDSAT USE

The states vary in their approaches to using Landsat. Some have found it advantageous to develop the necessary analysis capability internally in the state agencies. Others have worked cooperatively with universities while still others have contracted with private firms for Landsat analysis. A final alternative has been collaboration with other states, Federal agencies and universities for interstate Landsat investigations.

Landsat Within State Agencies

Two states, Texas and South Dakota, exemplify the development of Landsat analysis capabilities entirely within the framework of state government.

Texas Texas state agencies have been involved in a number of Landsat-oriented projects, most of them coordinated through the Texas Natural Resources Information System (TNRIS). Landsat projects undertaken by Texas state agencies have included coastal and land use/land cover mapping, an inventory of man-made reservoirs, mapping of East Texas forest lands, an inventory of the playa lakes on the Texas High Plains and several others. Taken together, these projects represent an important first step in establishing the remote sensing know-how necessary for a statewide system to inventory and manage the State's natural resources. To this end, TNRIS, the Texas General Land Office and NASA have recently begun activities to incorporate Landsat into a wide range of natural resource planning functions in the State.

South Dakota In South Dakota the Land Resource Information System (LRIS) is the principal focal point for the use of Landsat data. Charged by the State legislature with implementing the South Dakota Land Cover Inventory, the State Planning Bureau's LRIS is undertaking a program to apply land-cover data to many of the State's land management problems.

Using Landsat digital analysis techniques, LRIS has produced land cover maps of most of the State. As the staff has become more experienced, mapping costs have been reduced to around 14¢ per acre. Such low costs were made possible by the development of an analysis system tailored to meet South Dakota's specific natural resource data needs. The Land Cover Inventory provides data to a number of state, regional and local agency users including those concerned with water pollution control under the EPA "208" requirements. The South Dakota State Planning Bureau intends to continue using Landsat as an important tool in the planning and decision-making process.

Landsat in Agency/University Cooperative Programs

Georgia Landsat activities in Georgia are characterized by close cooperation between the Department of Natural Resources and the Georgia Institute of Technology. The Department of Natural Resources has completed land cover mapping for a large portion of the State using Landsat digital techniques. Computer facilities at the Georgia Institute of Technology were made available for the project and a close working relationship between the two groups has developed. NASA's Earth Resources Lab (ERL), located in Slidell, Louisiana, is supporting the project by providing technical advice and has transferred the necessary computer programs to the Georgia Tech Landsat digital analysis system.

The utility of Georgia's Landsat-derived land-cover data is demonstrated by the fact that a number of state and local agencies have used it to meet EPA Section "208" requirements. The U.S. Soils Conservation Service has used the data for the Conservation Needs Inventory; the U.S. Army Corps of Engineers has found the information useful for dredge-and-fill permitting purposes. These agencies have expressed their approval by furnishing substantial field support and cost-sharing assistance.

Georgia state government has found a common ground for working with Georgia Tech by establishing its own internal capabilities while utilizing university computer equipment and staff expertise. The same benefits from state agency/university collaboration could be realized in other states where there is an agency interest in the use of satellite technology and a willingness on the part of the university to provide ongoing services to the State.

Use of Private Industry

North Dakota The North Dakota Regional Environmental Assessment Program (REAP) was created by the 1975 North Dakota Legislative Assembly to carry out research on natural resources and to develop an information system for storage, retrieval and analysis of the resulting data. The REAP staff selected Landsat as the most efficient method for compiling statewide land-cover data, but rather than attempting to develop internal Landsat analysis capabilities, REAP relied on private industry. North Dakota thus became one of the first states to produce a set of land-cover maps of the entire state from Landsat data. Products from the Landsat analysis include a color-coded land-cover map; up-to-date land-cover area tabulations for the entire state and for each township and county, and a computer-tape file of land-cover data. This information provides an essential data base for the REAP system, and frequent updates will serve as a basis for monitoring statewide land-cover changes.

Illinois The Illinois Environmental Protection Agency (IEPA), the Illinois Department of Local Government Affairs (DLGA) and the Southwestern Illinois Metropolitan and Regional Planning Commission (SIMPAC) have contracted with private industry for a land-cover demonstration project based on satellite data. Products of the study, encompassing a 13 county, 7,500 square mile area, will find immediate applications in statewide water quality ("208") planning programs as well as in numerous functional planning activities at the regional and local levels. The involvement of a consultant was decided upon in order to reduce the time and costs required to develop a representative mix of Landsat products. Otherwise, participating agencies would have had to develop an internal capability involving a large and specialized staff as well as significant capital expenditures, which would not have been appropriate for a demonstration project.

The Illinois Landsat project has progressed to a feasibility study of statewide and multiple-user applications which could involve a number of other state, regional and local government entities. Because of perceived widespread applications and economic benefits, Landsat-related applications could play an increasingly important role in future natural resource planning in Illinois.

Regional Multi-State Approach to Landsat Use

Oregon, Idaho and Washington have participated with NASA in one of the most extensive Landsat programs to date, the Pacific Northwest Regional Commission (PNRC) Land Resource Inventory. The project involves classification and mapping of over fourteen million acres of land in the three states.

Each of the three states has its own unique areas of interest within the framework of the project and has developed the expertise necessary for these areas.

Idaho The Idaho Department of Water Resources, for example, used Landsat to inventory the State's 4,000,000 acres of irrigated agricultural land which is interspersed over a total area of 34,000,000 acres. Landsat is the only feasible way to inventory and maintain timely data on such a large area. The satellite analysis produced not only the basic inventory, but also a measurement of annual changes in irrigated acreage and a measurement of acreage in different crop types.

Oregon The Oregon Range Project, a wildlife habitat mapping effort, has the support not only of the PNRC and NASA, but of the Computer Center and the Environmental Remote Sensing Analysis Lab (ERSAL) at Oregon State University. Results of the project indicate that Landsat is an appropriate tool for habitat mapping. Costs of the project totaled $40,212 as compared to an estimated cost of $46,588 if done with aerial photography. The difference in time required, however, would have been much greater: 7.4 person-months for the Landsat approach compared to an estimated 25.5 person-months using aerial photos.

Washington The Washington State Department of Natural Resources has been a major participant in the PNRC Land Resources Inventory, with the goal of conducting a complete forest inventory of the State. Once developed, the inventory will facilitate accurate projections of potential timber harvests and trends. Each acre of forest area is classified into one of several broad groups such as hardwood or conifer. Forest areas are further classified by ownership group. Finally, this information is displayed in map form and tabulated in computerized files. All of this is done for about half the cost estimated for general inventory surveys using other methods.

The PNRC Land Resources Inventory demonstrates the utility of cooperative efforts among federal and state agencies, universities and the private sector for broad-scale Landsat investigations. Landsat is most appropriate for projects covering large geographic areas, and this often calls for the combined expertise of diverse groups. The PNRC Land Resources Inventory Project has shown how such groups can work together toward common goals. With the growing awareness that environmental problems are not confined by state or other political boundaries, regional, multi-state approaches to Landsat use may become increasingly popular.

Advantages of the Different Approaches

Each of the institutional approaches to Landsat use has advantages. Development of internal capabilities for Landsat processing, including the necessary computer equipment and analysis expertise, may be somewhat costly for a single effort, but it may prove cost effective if a state intends to use satellite data on a continuing basis. State agency/university cooperation is a potential low-cost approach for states which are not yet prepared to make a large investment in Landsat technology. If results are favorable, the technology can gradually be transferred to the state agencies. In general, collaboration with universities offers great potential, but, owing perhaps to a lack of common goals, such relationships are often difficult to establish. Contracting for Landsat analysis with a private firm is often the preferred approach if only a one-time effort is planned. In working with private industry it is most important that the state agency personnel be well informed about the technology and have a clear idea of the type of product needed. The regional multi-state approach has the advantage of providing expertise and facilities from a wider range of sources and, very importantly, offers the opportunity to study broad-scale environmental features which, in many cases, cross state boundaries.

V. FUTURE OF THE LANDSAT PROGRAM

Plans for the future of Landsat call for solving several fundamental problems which have hampered the satellite system so far. Principal difficulties include the time lag (often 2 months) between the time the satellite records the image and the time the data is made available to the user, the lack of a heat sensor and the poor resolution or detail.

Landsat-3

A new data distribution system is being phased into operation in conjunction with Landsat-3 (launched in March of 1978) which will make the satellite data available within two weeks after it is originally recorded. Instead of shipping the raw data to Goddard by mail from the receiving stations, the new system will transmit the data across the country via communications satellite. After undergoing certain processing procedures at Goddard Space Flight Center in Greenbelt, Maryland, the data will be transmitted, again by satellite rather than via mail, to the EROS Data Center in Sioux Falls, South Dakota, where it will be available for purchase. The new distribution system will make Landsat data much more timely and allow monitoring efforts to take place in a near "real-time" mode.

An additional feature of Landsat-3 is a thermal infrared or heat sensor. This device can detect temperature differences of as little as 3°C or 4°C, a potentially important capability for mineral, geothermal and other applications. Improvements in the television sensor, particularly a much improved resolution, are expected to increase the utility of the system for applications which require greater detail.

Landsat-D

Landsat-D, which will be renamed Landsat-4 after it is successfully launched, is scheduled to begin operation in the fall of 1981. In addition to the multi-spectral scanner carried by the first 3 satellites, Landsat-D will carry a sensor known as the "Thematic Mapper" which will provide resolution approximately five times as detailed as its predecessors. The new sensor will be able to discriminate area features as small as .2 acres as compared to the 1.1 acre resolution of present systems. The greater detail, along with the improved distribution system initiated under Landsat-3, will enable states to extract much more detailed and timely information.

A National Conference of State Legislatures' task force study found that users expect the improved detail of Landsat-D to be particularly advantageous for the following applications:

- Urban and metropolitan area planning
- Identifying timber types by species
- Geologic and hydrologic mapping
- Wetlands mapping
- Mapping inland water quality parameters
- Route and site selection
- Crop disease and insect infestation detection

With its technical improvements, Landsat-D will represent a major step toward the operational capability which is necessary if the public is to realize the full benefits from remote sensing technology. The U.S. Congress has initiated hearings on the need for an approach to developing an ongoing Landsat program. The Administration, through the Office of Science and Technology Policy and The Intergovernmental Science, Engineering and Technology Advisory Panel, is conducting a comprehensive study of Landsat technology and policies with a view towards making Landsat more useful.

VI. LANDSAT INFORMATION SOURCES

Information on Landsat technology is available from a number of sources. Many of these sources employ personnel trained to explain to potential users the steps necessary to begin applying Landsat data to state problems.

NCSL Remote Sensing Program

The National Conference of State Legislatures (NCSL) established a task force in 1976 to review the feasibility of using Landsat technology in state and local government. The NCSL task force determined that Landsat data was uniquely suited to satisfy many state legislative information needs and unanimously endorsed continuation of the satellite program. In addition, they made specific recommendations for aiding the transfer of this new technology from the Federal government to the states.

To implement these and other recommendations, NCSL initiated a Satellite Remote Sensing Program directed toward informing state lawmakers of the capabilities and limitations of Landsat technology. The project is designed to foster communication between the states and satellite remote sensing experts in the private sector, the universities, NASA and in other agencies of the Federal government. To this end, NCSL has conducted regional and state-level remote sensing workshops throughout the country. Additional workshops will be held in coming months in states expressing interest.

For further information or assistance, contact Mr. Paul Tessar, Director of the Satellite Remote Sensing Project at NCSL Denver Office, 1405 Curtis Street, 23rd floor, Denver, Colorado, 80202, telephone (303) 623-6600.

NASA

NASA's Office of Space and Terrestrial Applications serves as a liaison between NASA and Landsat users and provides information to the states, as well as to other user communities, about Landsat capabilities. This NASA office can direct potential users of Landsat to the appropriate regional facility for assistance.

Regionally, NASA conducts a Remote Sensing Applications Program to assist states in the use of Landsat technology for operational problems. Branches of this program have been established at three NASA field installations, each with responsiblities for the states in its specific geographic region. The Northeast, Middle Atlantic and Great Lakes areas are served by the Goddard Space Flight Center in Greenbelt, Maryland. The South and Midwest are in the area of the NASA Earth Resources Laboratory in Slidell, Louisiana. Western states should contact the Ames Research Center in Palo Alto, California. Personnel from each of these regional offices are prepared to answer any questions from state-level users about applying Landsat technology to state needs.

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U.S. Department of the Interior

The U.S. Department of the Interior Earth Resources Observation Systems (EROS) Data Center, administered by the U.S. Geological Survey, is responsible for the storage, reproduction and distribution of Landsat data, imagery from other satellite programs and aerial photography acquired by the federal government. The Data Center houses a master data archive, a precision photographic laboratory and a computer complex. It includes a staff of applications scientists engaged in training, transfer of remote sensing technology and special applications projects. As part of its training program, EROS offers short courses on the use of Landsat and other remote sensing technology.

For further information, contact the EROS Data Center, Sioux Falls, South Dakota, 57198, telephone (605) 594-6511. Inquiries concerning the availability of coverage may be directed to User Services. Information on technical aspects of remote sensing or training programs may be directed to the Branch of Applications.

The U.S. Geological Survey's National Cartographic Information Center (NCIC) operates an information service for satellite imagery, aerial photography and all U.S.-produced maps and charts. NCIC maintains Landsat browse files in its Reston headquarters as well as its regional and state affiliate offices so that users may view the imagery in microfilm form. For additional information and the address of the nearest NCIC office, contact the National Cartographic Information Center at (703) 860-6045.

State Agencies

Landsat information is available from the following state agencies which have centralized remote sensing programs:

State	Contact
Arizona	Michael S. Castro Arizona State Land Dept. Information Resources Division 1624 W. Adams, Room 302 Phoenix, AZ 85007 (602) 255-4061
California	Tim Hays Environmental Data Center Office of Planning and Research 1400 Tenth Street Sacramento, California 95814 (916) 322-3784
Florida	Bill Kuyper Remote Sensing Engineer State Topographic Office Dept. of Transportation Haydon Burns Building Tallahassee, Florida 32304 (904) 488-2168

Georgia	Bruce Q. Rado Georgia Department of Natural Resources 19 Martin Luther King Jr., Dr. Room 414 Atlanta, Georgia 30334 (404) 656-3214
Idaho	Alan Porter Division of Budget, Policy Planning and Coordination State House Boise, Idaho 83720 (208) 384-3900
Iowa	Bernard Hoyer Iowa Geological Survey 123 North Capitol Iowa City, Iowa 52242 (319) 338-1173
Kentucky	Craig Erickson Department of Natural Resources & Environmental Protection 407 Capitol Plaza Towers Frankfort, KY 40601 (502) 564-7320
Maryland	Dale Johnson Department of State Planning State Office Building, Room 1101 301 West Preston Street Baltimore, Maryland 21201 (301) 383-3067
Minnesota	Donald P. Yaeger Mapping and Remote Sensing Information Center State Planning Agency 15 Capitol Square Building St. Paul, Minnesota 55101 (612) 296-1211
Mississippi	Paul Edward Downing Research and Development Center P.O. Box 2470 Jackson, Mississippi 39205 (601) 982-6339

Montana	Thomas Dundas, Administrator Research and Information Systems Division Department of Community Affairs Capitol Station Helena, Montana 59601 (406) 449-2896
New Jersey	Bob Mills Bureau of Planning and Automated Systems 88 East State Street Trenton, NJ 08625 (609) 984-7730
New Mexico	Gerald Gates Department of Fish and Game Villagra Building Santa Fe, New Mexico 87503 (505) 827-5446
North Carolina	John Higgins Department of Natural Resources and Community Development P.O. Box 27687 Raleigh, North Carolina 27611 (919) 733-2090
Ohio	Garry Schaal Ohio Department of Natural Resources Fountain Square Columbus, Ohio 43224 (614) 466-6557
Oregon	Ken Hansen Land Conservation and Development Commission 1175 Court Street, N.E. Salem, Oregon 97310 (503) 378-2978
South Carolina	Gerald Minick University of South Carolina Computer Service Division—Graphics Section Middleburg Plaza Columbia, South Carolina 29205 (803) 777-7237
South Dakota	Dick Gebhart Land Resource Information System State Planning Bureau State Capitol Pierre, South Dakota 57501 (605) 773-3628

Texas	Samuel McCulloch Texas Natural Resources Information System P.O. Box 13087, Capitol Station Austin, Texas 78711 (512) 475-3321
Vermont	M. Brian Stone Chief of Project Management Department of Forest, Parks and Recreation Agency of Environmental Conservation Montpelier, Vermont 06502 (802) 828-3375
Virginia	William E. Breen Chairman, VARIS Task Force Office of Commerce & Resources 5th Floor, 9th St. Office Bldg. Richmond, Virginia 23219 (804) 786-7831
Washington	Mike McCormick Office of Community Development Room 400 Capitol Center Building Olympia, Washington 98504 (206) 753-1928

Private Sector

Many companies in the remote sensing industry offer a variety of hardware, software and services of potential interest to state and local government. The matrix on the following pages presents a summary of the assistance available from a representative sample of the private sector firms involved in Landsat technology. Landsat capability statements from the companies listed on the following pages were not included here due to space limitations, but are available upon request from the NCSL Remote Sensing Project.

	HARDWARE			SOFTWARE			
	Optical Image Interp	Computer Analysis Systems	Computer Hardware	Landsat Processing	Geo-based Information Systems	Machine Compatibility	
						Language	Hardware Required
Bausch & Lomb	X						
Calspan Corporation	X						
Comarc Design Systems		X			X	Fortran	Eclipse S230
Earthsat Corporation				X	X	Fortran IBM Assembler	IBM 370
Environmental Research Institute of Michigan — ERIM		X		X	X	N/A	N/A
Environmental Research and Technology					X	N/A	N/A
ESL		X	X	X	X	Fortran SPL	HP 3000
Floating Point Systems			X				
Ford Aerospace and Communications Corporation		X	X	X		Fortran	PDP11/45
General Electric		X	X				
Lockheed Electronics Company, Inc.		X	X	X	X	N/A	N/A
Resources Development Associates							
W.E. Gates & Associates					X		

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	SERVICES								
				Data Analysis					
	Systems Design	Feasibility Studies	Consulting	Pre-Processing	Rectification	Categorization	Tabulation	File Creation	Map Production
Bausch & Lomb									
Calspan Corporation				X					
Conarc Design Systems	X	X	X						
Earthsat Corporation	X	X	X	X	X	X	X	X	X
Environmental Research Institute of Michigan — ERIM	X	X	X	X	X	X	X	X	X
Environmental Research and Technology			X						
ESL	X	X	X	X	X	X	X	X	X
Floating Point Systems									
Ford Aerospace and Communications Corporation	X	X	X			X			
General Electric	X	X	X	X	X	X	X	X	X
Lockheed Electronics Company, Inc.	X	X	X	X	X	X	X	X	X
Resources Development Associates	X		X			X	X	X	X
W.E. Gates & Associates	X	X	X						

VII. SUMMARY AND CONCLUSION

Landsat offers state legislators, planners and resource managers a new source of information of significant current and potential value for a wide range of natural resource investigations. For many uses it has proven to be more efficient and economical than alternate data sources. In some instances it provides the only economically feasible means to collect the data required by recent federal, state and local resource management programs.

Landsat's repetitive and wide-area coverage offers the capability to analyze and monitor changes which occur over large geographic areas. The ability to keep track of changes in land cover is especially important in light of recent legislation requiring frequent environmental monitoring. The broad area covered by each Landsat scene offers a new perspective which has numerous practical applications.

The use of Landsat is easily within the means of every state, both in terms of financial resources and technical expertise. Landsat processing can be done manually by aerial photo interpretation or by computers which are already in use in all states.

States have successfully followed several different instutional approaches to Landsat use. Whether a state develops its own Landsat analysis capabilities, works cooperatively with local universities, contracts with private industry or works in conjunction with neighboring states, depends entirely on individual needs and circumstances. Whichever approach or combination of approaches is selected, Landsat data is accessible. Several federal facilities are working to make it even more easily available and useful for the unique requirements of each state.

Landsat does not offer an answer to all problems. Despite its limitations, however, it has proven to be well suited for helping to solve many of the most pressing environmental problems faced by state government. It is a new and useful tool which, when used with an understanding of its capabilities as well as limitations, can be a great asset to any state.

VIII. GLOSSARY

CCT	— Computer Compatible tape of Landsat data
Computer Compatibility	— The capacity of Landsat data to be processed by computer
Electromagnetic Spectrum	— The range of light wavelengths that can be recorded by remote sensors
EPA "208"	— Environmental Protection Agency Section 208 Area-Wide Water Quality Planning Program
EROS	— Earth Resources Observation System
ERTS	— Earth Resources Technology Satellite (later renamed "Landsat")
HUD 701	— Section 701 of Housing and Community Development Act of 1954, as amended
Imagery	— The picture that results from remote sensing
Infrared	— A portion of the electromagnetic spectrum beyond the visible region with wavelengths longer than those of visible light
LACIE	— Large Area Crop Inventory Experiment — A NASA demonstration project
Landsat	— The satellite that identifies characteristics of land and water features. Formerly known as ERTS
MSS	— Multispectral Scanner, the principal imaging device in Landsat
Multispectral	— The use of one or more sensors to obtain imagery from different portions of the electromagnetic spectrum

Multispectral Scanner	— The Landsat mirror mechanism that detects reflected light from earth and directs it to the satellite's sensors
NASA	— National Aeronautics and Space Administration
NCIC	— National Cartographic Information Center
Reflectance	— The measure of the ability of an object to reflect light
Remote Sensing	— The ability to record information about an object without coming into direct contact with it
Resolution	— The ability of a remote sensing system to distinguish features on the earth's surface. As resolution becomes finer, the image detail increases and smaller objects become visible. In Landsat-1, -2 and -3, the resolution is 79 meters. In Landsat-D it will be 30 meters
Sensor	— An instrument used to detect and/or record electromagnetic energy associated with an environmental phenomenon
Thermal Infrared	— Electromagnetic energy between wavelengths of about 3 um and 1,000 um. A thermal-infrared sensor detects heat emissions
Trophic Level	— Nutrient level. Generally used in regard to fresh water lakes
Windshield Survey	— A survey done from an automobile. Only areas visible from the road are recorded